FACULTY OF ENGINEERING AND ARCHITECTURE

NETWORK AND COMPUTER SECURITY

SUMMARY

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CONTENTS

1 INTRODUCTION

1.1 Security in the media

- Security <=> User friendly: work of security personel goes unnoticed when everything is good, but they get blamed when things go wrong.
- Users remains a security risk:
  - Due to lack of knowledge: *1 in 10 in a survey think HTML is an STD - Los Angeles Times* [1]
  - Due to incompetence
  - Information can stell be shared non-digitally
- Nobody is safe: *NSA hackt Belgische cyberprof - De Standaard* [2]
- Privacy vs Security: sacrificing privacy so data can be used for security.
  - *AIVD hackt internetfora, 'tegen wet in' - NRC* [3]
  - *Révélations sur le Big Brother français* [4]
- Check yourself using `https://haveibeenpwned.com/`
- Privacy vs Health: tracing apps in times of COVID-19
- Journalists aren't alwasy exactly IT experts →remain a critic, remain sceptic
- Future trends: blockchains
  - mainly used for data integrity through **public ledgers**
  - Used to log activity.
    - Detect malicious operations, hackers, foreign surveillance, database modifications
    - Equally important as access restrictions
- Future trends: cyber warface
  - Nation wide actions to cause damage or disruption. Can include physical impact and/or harm to human persons
  - Interesting targets: traffic lights, electricity systems, water filtration, power plants
  - Stuxnet:
    - Worm that targeted Iranian nuclear facilities, damaging centrifuges and other hardware
    - Most likely an American-Israeli cyberweapon
  - Petya: ransomware or state attack?
    - Focused strongly on Ukraine systems
    - Made very little money
    - Either very bugge, or very damaging by purpose: permanent removal of files, nuclear power plants, ministries, metros and banks offline, possible link with assassination of Maksym Shapoval
  - Future trends: IoT: *Docs shielded Cheney defibrillator from hacks - CNN* [5]

1.2 Example Incidents

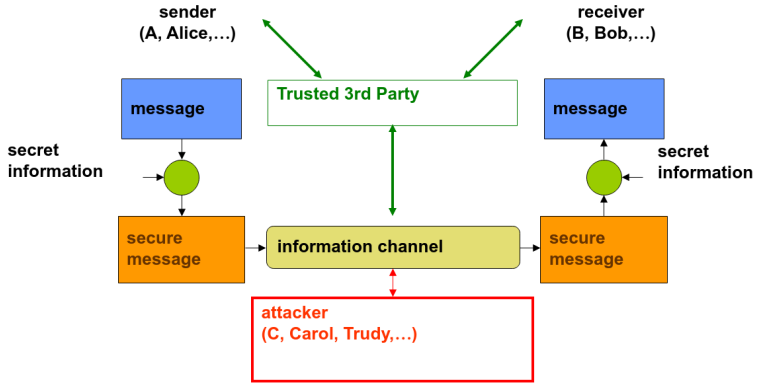
- Ashley Madison (2015)
- DNC email leak (2016)
- Mirai (2016)
- Twitter hack (2020)

1.3 Why do we need security? Why Information Security?

- Counterpart of securing material objects
  - Material object have some **value**
  - Can be stolen or damaged
  - Cost for security/protection takes into account value and risk of theft/damage
- Risk of threats against information security is **much** greater
- Value of information sometimes hard to assess, best estimated by damage caused. Losses cannot be undone
- Threats against information include:
  - **Loss** of information
  - **Forged** information
  - **Unauthorised release** of information
  - **Repudiation** of information
- Value of information systems hard to asses. Systems used to enable service →damage when service unavailable or unreliable
- Threats against information systems include:
  - **Unavailability**/disruption of service
  - **Unauthorised acces** to service
  - Threats against exchanged information
- Security measures for information systems:
  - **Information Security**: encryption, virus scanners, firewalls…
  - Carry some cost (installation, maintenance, computation time)
  - dependent on risk and potential damage

2 BASIC CONCEPTS

2.1 A security model



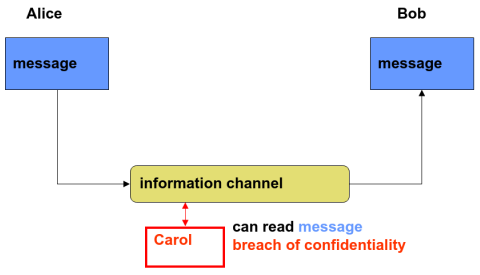
2.2 Security Goals

Possible exam questions:

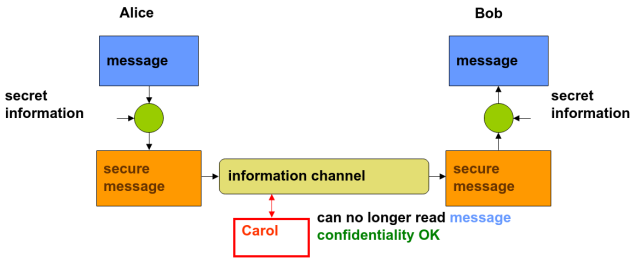
- **Which security goals does this protocol fullfill?**
- **Which security goals per chapter?**

2.2.1 Confidentiality

- Data can only be read by those who are allowed to read the data
- Applications:
  - Communicating confidential data between branches of a corporation
  - Passwords
  - Storage of health data



(a) Passive attack by Carol: **eavesdropping** upon information channel



(b) Solution to eavesdropping

Traffic-flow confidentiality

- Keeping secret who's communicating with whom
- Much harder to achieve than data confidentiality
- In Figure 2.1b data confidentiality is OK, traffic-flow confidentiality is NOT OK: Carol can still see that Alice is communicating with Bob

Confidentiality vs Privacy

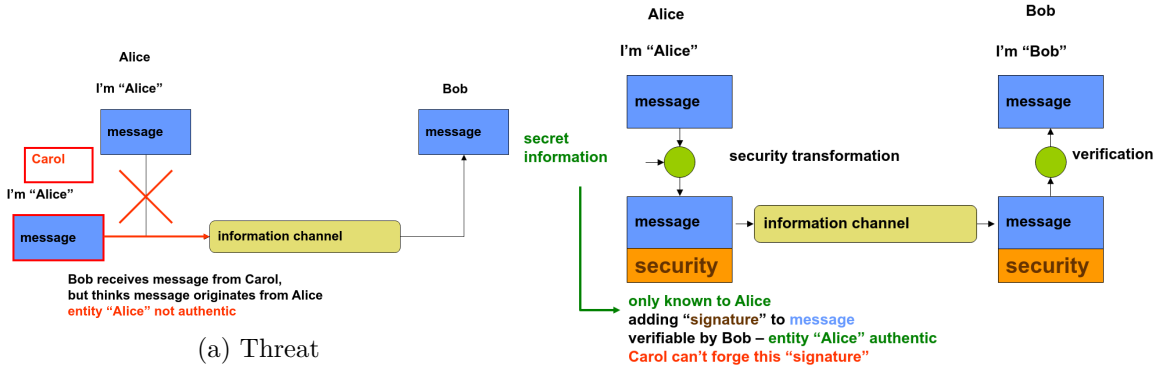
Privacy is having the right to choose what information you give away. It is a fundamental right, legally protected since long. Not every confidentiality requirement involves privacy: intellectual property in a business requires confidentiality, no privacy.

2.2.2 Authentication

Authentication is related to **identification**: it is the *electronic world* equivalent. *Is the person at the other end of the communication who he claims he is?*

Guaranteeing teh authenticity of a communication is based on:

- **Entity** authentication: distinguish each entity from another based on collection of data. Each entity has a unique identity.
- **Attribute** authentication. Attribute = characteristic of an entity. Entities are often authenicated through authentication of some of its attributes. Do the communicating parties exhibit the characteristics they claim to have?
- **Data-origin** authentication: does the data indeed originate from the specified source? Important to evaluate wether data is reliable (**Data Integrity** see 2.2.4). Different from entity authentication: **no interaction with data source**.



(a) Threat

(b) Solution

2.2.3 Access Control/authorization

- Determines which user may access which resource (data, computation time, etc.)
- Requires **authentication of the entity** requesting access to these resources
  - System determines to what extent entity may access those resources
  - Access rights may **depend on entity itself or its attributes**

Illustration 1: access control in OS

- Authentication through login and password
- Access control determined for this user (entity)
  - Full access to own files
  - Limited acces to some other files
  - No acces to other files
- Access rights different from user to user

Illustration 2: access control to medical database

- Different rights for different types of Users
- Requires authentication based on specific **attributes**
- Access rights depend on attributes of the user
- Access rights different from user type to user type (**roles**)

2.2.4 Data integrity

- Guarantee that sent data and received data are identical
  - No tampering with data en route
  - Nothing was added
  - Nothing was deleted
  - Nothing was modified
  - Nothing was replayed
- stronger requirement than data origin authentication: data originates from specified source **AND** isn't changed on the way
- Threats
  - Messages can be replayed
  - Messages can be altered
  - Cannot be solved with confidentiality (encryption): encrypted messages can also be replayed

Solution

A security footer containing a sequence number which can only be generated by the sender. This footer has to be generated based on the whole message to prevent tampering to the message itself. No need to encrypt the whole message for data integrity, but the message is not confidential if it isn't encrypted.

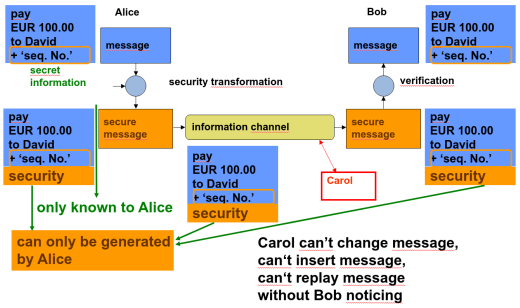


Figure 2.3: Data integrity solution

2.2.5 Non-repudiation

- Sender can't deny having sent the message. Important for receiver. *Prove order has been placed*
- Receiver can't deny having received the message. Important for sender. *Prove invoice has been paid*
- Both sides need to communicate and 'sign' their messages to guarantee non-repudiation for both sides.

2.2.6 Availability

- System/service is accessible and usable for authorised Users
- Security context $\leftrightarrow$ System design context

Threats

- DoS: denial-of-service: target swamped by torrent of messages from attacker
- DDos: distributed denial-of-service: target swamped by torrent of messages from multiple (and numerous) senders (botnets).

2.3 Security Threats

Possible exam questions:

- **Explain the difference between confidentiality, authentication, acces control/authorization, data integrity, non-repudiation and availability.**
- **Which of the above security goals are realized in the network protocols from Chapter 4?**
- **Why are sequence numbers (or nonces) added to messages? Is it a good idea to use a time stamp for this purpose?**
- **Which counter measurements can be taken against DoS and DDoS attacks?**
- **Give 5 examples of active attacks that can be used to compromise the security of a network protocol.**
- **Passive** attacks
  - Eavesdropping
  - Traffic analysis
- **Active** attacks
  - Message insertion/modification
  - Impersonation/masquerade
  - Replay
  - DoS
  - Hijacking (taking over existing connection, where attacker replaces sender or receiver)

Hackers first seek a weak point in a network (for example through social engineering), second they wil use passive attacks to gain more information. Lastly they'll use active attacks.

2.3.1 Possible attacks

- Brute force: Trying all possible keys
- Cryptanalysis: using knowledge about structure of algorithm, pairs of plaintext and secure messages in order to recover plaintext message or key itself, or to forge secure message
- Side-channel attacks use physical properties or fault injection in order to recover plaintext or key
  - *Here's How iPhone Thermal Cameras Can Be Used to Steal Your Pin Codes* [6]
  - *Researchers crack the world's toughest encryption by listening to the tiny sounds made by your computer's CPU - ExtremeTech* [7]

2.3.2 Categories of attacks

- **Ciphertext only**: only secure message is known to attacker. Hardest one to break.
- **Known plaintext**: one or more pairs obtained with a single key are known to attacker. Easier to break, but still safe.
- **Chosen plaintext**: one or more pairs obtained with a single key, plaintext chosen by attacker. Harder to get, easier to break.
- **Chosen ciphertext**: one or more pairs obtained with a single key, ciphertext chosen by attacker (plaintext can be garbage). Even harder to get, easier to break.
- **Chosen text**: combination of chosen plaintext and chosen ciphertext.

2.3.3 Desired degree of security?

- Unconditionally secure is **not achieved by any practical security mechanism**.
- Computationally secure means that the **time required for breaking is longer than the usefull lifetime** of the information, or that the **cost of breaking the encryption is larger than the value** of the information.

3 ENCRYPTION ALGORITHMS

3.1 Steganography

- Steganography: conceal the existence of the message.
- Cryptography: render message unintelligible
- As old as (or older) than cryptography. Used heavily in history
- Alter digital files (audio, sound, text, pictures…) to a certain extend without losing their functionality. Exploiting the human inability to distinguish minor changes.

3.1.1 Watermarking

Noise can be used as a watermark: the statistic distribution gives info about creator (and copyright information). Try to implement the noise so that it cannot be removed or modified by any signal processing operation without degrading perceptual quality. The watermark should be perceptually invisible.
Applications include:

- Covert information exchanges
- Establish identity
- Combat illegal copying

The biggest drawback is the high overhead to hide relatively few info bits.

3.2 Encryption througout history

Encryption is an alternative for steganography.

3.2.1 Substitution ciphers

Monoalphabetic Substitution Ciphers

Simplest version: shift letters X places (Caesar Cipher: $X = 3$). Disadvantage = only 25 keys ($X = 26$ is no cipher), which is easily bruteforceable.

$$E(p) = (p + k) \ \% \ 26$$
$$D(c) = (c - k) \ \% \ 26$$

By shuffling the letters arbitrarily (each plaintext letter maps to a differnt random ciphertext letter) we can extend the key to 26 letters, which makes it not bruteforceable. Still not fully secure because after analysing the letter frequencies it is relatively easy to decrypt the ciphertext. **Monoalphabetic substitution ciphers do not change relative letter frequencies**.

Polyalphabetic Substitution Ciphers

Further security improvements by using multiple cipher alphabets sequentially.

- **Alberti cipher**: Rotate an encyrption disk every few letters
- **Vigenère cipher**
  - More generic
  - key = multiple letters ($K = k_1 k_2 \dots k_d$)
  - i^{th} letter specifies i^{th} alphabet to use
  - repeat from start after d letters in message
  - Decryption simply works in reverse, and is thus relatively fast
  - Relativity safe, frequency analysis not possible anymore

Rotor machines such as the *Hagelin machine* or *enigme* are examples of polyalphabetic ciphers.

Digraph Substition Ciphers

Playfair cipher: reduces predictability of language by encrypting multiple letters simultanuously. It uses a 5x5 matrix of letters based on a keyword (without duplicate letters). Security is much

Plaintext is encrypted two letters at a time

1. **if a pair is a repeated letter, insert filler like 'X'**
   - balloon -> ba lx lo on
2. **if both letters fall in the same row, replace each with the letter to right (wrapping back to start from end)**
   - ar -> rm
3. **if both letters fall in the same column, replace each with the letter below it (again wrapping to top from bottom)**
   - mu -> cm
4. **otherwise each letter is replaced by the letter in the same row and in the column of the other letter of the pair**
   - hs -> bp

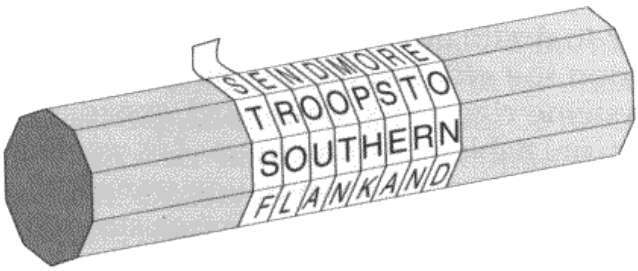
M	O	N	A	R
C	H	Y	B	D
E	F	G	I/J	K
L	P	Q	S	T
U	V	W	X	Z

Figure 3.1: Playfair cipher encryption

improved since we have 676 (26x26) diagrams versus 26 for a monoalphabetic cipher. Another advantage is that this cipher is easier to use since no machinery is needed. It was widely used eg. by US & British military in WW1, but can now easily be broken, given a few hundred letters.

3.2.2 Transposition ciphers

Rearranging the letter order. Not susceptible to frequency analysis since ciphertext has same frequency distribution as plaintext.
Some examples:



Roll of the ciphertext.

Figure 3.2: ScyTale

D				N				E				T				L		
	E		E		D		H		E		S		W		L		X	
		F				T				A				A				X

Write message letters diagonally over a number of rows, then read off cipher row by row.
defend the east wall → dnetleedheswlxftaax

Figure 3.3: Rail Fence cipher

```
Key:        3 4 2 1 5 6 7
Plaintext:    a t t a c k p
                  o s t p o n e
                  d u n t i l t
                  w o a m x y z
Ciphertext: TTNAAPTMTSUOAODWCOIXKNLYPETZ
```

A more complex transposition. Write letters of message out in rows over a specified number of columns, then reorder the columns according to some key before reading off the columns.

Figure 3.4: Columnar Transposition Cipher

3.2.3 Combination ciphers

Both substitution and transposition have frequency and pattern analysis as vulnerabilities respectively. What about multiple ciphers in succession?

- Multiple substitution just make a more complex substitution
- Multiple Transpositions just make a more complex transposition
- **Substitution followed by a transposition makes a new much harder cipher**

3.3 Modern cryptography

3.3.1 Symmetric encryption algorithms

3.3.2 Asymmetric encryption algorithms

3.3.3 HASH algorithms

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